ALGAL POPULATIONS IN BOTTLE HOLLOW RESERVOIR, DUCHESNE COUNTY, UTAH

Jeffrey Johansen[1], Samuel R. Rushforth[2], and Irena Kaczmarska[3]

Abstract.— Bottle Hollow Reservoir contains a diverse algal flora. A total of 289 taxa was observed, 227 of which were diatoms. Both littoral and planktonic communities had high diatom diversity. During summer months filamentous Chlorophyta were diverse and high in biomass in the littoral zone. Phytoplankton collections in Bottle Hollow Reservoir were dominated by four species: *Asterionella formosa*, *Cyclotella comta*, *Dinobryon divergens*, and *Fragilaria crotonensis*. Plankton samples contained mostly small diatoms in early spring, with larger algae succeeding these as the summer progressed. No blue-green algae were important in this succession. Two peak production periods were observed, one in the fall and one in the spring. Bottle Hollow Reservoir appears to be a healthy mesotrophic system based on the evidences of moderately high algal diversity, insignificance of blue-green algae, and the presence of a suite of diatom species indicative of mesotrophic conditions.

Bottle Hollow Reservoir is in Fort Duchesne, Duchesne County, Utah, on the Ute Indian Reservation. It was planned and constructed by the Bureau of Reclamation as a mitigation component of the Bonneville Unit of the Central Utah Project. The primary function of this reservoir was to replace part of the fisheries and recreation lost due to the construction of the Rock Creek component of the Central Utah Project. Bottle Hollow Reservoir is presently the central component of the Bottle Hollow Resort owned and operated by the Ute Indian Tribe. It is used primarily for sport fishing.

Construction of Bottle Hollow Reservoir was completed in 1971 and the lake was filled during 1972. Water for the reservoir is taken from the Uinta River through the Indian Bench Canal that originates 11 km to the northwest. Little outflow is released from the reservoir at any time of the year. Water to replace that lost by evaporation and seepage is brought from the Uinta River through the Indian Bench Canal during the early spring. No appreciable flushing or flow-through has occurred in the reservoir since its completion. Total capacity of Bottle Hollow Reservoir is 11,103 acre feet, with usable capacity at essentially the same figure. Elevation of the spillway is 1552.8 meters, and surface area of the reservoir is 418 acres.

Fishing in Bottle Hollow has been good to excellent since its completion. The fishery is based primarily upon planted brown trout (Merritt et al. 1980). Concern to maintain this fishery and concern over somewhat poorer catches during the past few years led the Ute Indian Tribe to initiate a comprehensive study of the water quality and biology of the system. This study was financed by the Environmental Protection Agency through an areawide 208 water quality planning grant. We have studied the algal floras of this reservoir during 1977 and 1979–1980.

Methods

Ten collection stations were established to monitor the plankton and attached algae in Bottle Hollow Reservoir (Fig. 1). The first five were identical to the water quality stations used by Merritt et al. (1980) for chemical and physical analyses of the reservoir. Littoral collections were made at four sites around the periphery of the reservoir: the shore near the inlet channel, the north end, the south dam, and the south end. The inlet channel itself was also sampled. Four series

[1]Department of Oceanography, Texas A & M University, College Station, Texas 77843.
[2]Department of Botany, Brigham Young University, Provo, Utah 84602.
[3]Polish Academy of Sciences, Institute of Botany, Department of Phycology, ul. Lubicz 46, 31-512 Krakow, Poland.

of collections were made during the 1979–80 study period (Table 1).

Plankton samples were collected using a 2.3 liter capacity Van Doren bottle. Four Van Doren bottles distributed evenly through the euphotic zone were collected at each phytoplankton site and filtered through a 35 mm mesh phytoplankton net into a large bucket, yielding a composite net plankton sample for each site. In addition, a composite nannoplankton sample was collected by sampling the filtrate in the bucket. Sediment samples were collected using an Ekmann Dredge.

Littoral algal collections were chiefly of attached species, though twice unattached filamentous green algae were collected (Table 1). Attached algae consisted of epiphyton (algae growing on vascular plants), epilithon (algae attached to rocks), and epipsammon (algae growing on and in sand or silt).

Samples were returned to Brigham Young University and placed under refrigeration. Analyses of living algae were made within one week after collection. Nannoplankton samples were concentrated by vacuum filtration through Millipore filters (1.2 mm pore size). Estimates of absolute densities of planktonic algae were made using Palmer Cell water mounts. Living algae in littoral and benthic samples were identified and the abundance of each species estimated.

After living algae were studied, the diatoms in each sample were cleaned, using standard nitric acid oxidation techniques (St. Clair and Rushforth 1976), and mounted in Hyrax resin. All algae were examined and identified using Zeiss RA research microscopes with phase contrast and Nomarski interference phase accessories.

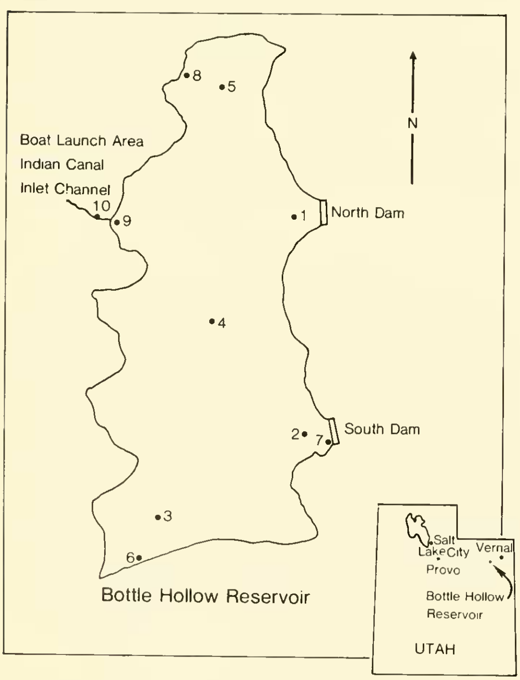


Fig. 1. Reference map of Bottle Hollow Reservoir showing the collecting localities.

Results

A total of 280 algal taxa were observed during this study. Twenty-three of these were blue-green algae (Cyanophyta); 32 were green algae (Chlorophyta); 4 were euglenophytes (Euglenophyta); 2 were dinoflagellates (Pyrrhophyta); one was a chrysophyte (Chrysophyta); and 227 were diatoms (Bacillariophyta). All algal species, together with their occurrence in the major microhabitats of the reservoir, are listed in Table 2. Living algae were not observed in any of the sediment collections, and so diatom slides made from these samples were not quantitatively analyzed.

Littoral communities were dominated by filamentous green algae most of the year. These were chiefly representatives of

Table 1. Algal samples collected from Bottle Hollow Reservoir during the 1979–1980 sampling period. All samples were examined for nondiatoms. Permanent diatom slides of samples from stations 1–6 and 9 were also examined. Key: P = plankton; S = sediments; Ep = epiphytic algae; El = epilithic algae; Es = epipsammic algae; L = littoral unattached algae.

Station	15 Nov 1979	27 Mar 1980	20 Jun 1980	26 Jul 1980
1	P, S	P, S		
2	P, S	P, S	P	P
3	P, S	P, S		
4	P, S	P, S		
5	P, S	P, S		
6	Ep, Es	Ep, Es	Ep, Es	El, Es
7	El, Es		El	El
8	El, Es, L		L	El, Es
9	Ep, Es	Ep, Es		Es
10	El		El	El

TABLE 2. Algal species collected from Bottle Hollow Reservoir, Duchesne County, Utah, with their distribution in the various habitats studied.

Species	Inflow	Benthos	Epiphyton	Epipsammon	Epilithon	Plankton
CYANOPHYTA						
Anabaena variabilis Kuetzing	x		x	x		
Anabaena sp.			x	x		
Aphanizomenon flos-aquae (Lemm.) Ralfs			x	x	x	
Calothrix sp.					x	
Chroococcus limneticus Lemmermann			x	x	x	
Chroococcus turgidus (Kg.) Naegeli						x
Gloeocapsa decorticans (A. Br.) P. Richt.				x		
Gomphosphaeria aponina var. *delicatula* Virieux				x	x	x
Lyngbya birgii G.M. Smith					x	
Lyngbya diguetii Gomont	x					
Merismopedia glauca (Ehr.) Naegeli			x			
Nodularia spumigena Mertens	x					
Oscillatoria agardhii Gomont		x	x			
Oscillatoria angusta Koppe			x	x	x	
Oscillatoria geminata Schwabe			x			
Oscillatoria limnetica Lemmermann	x			x	x	
Oscillatoria limosa (Roth) Agardh			x	x	x	
Oscillatoria subbrevis Schmidle	x			x	x	
Oscillatoria tenuis Agardh			x	x	x	
Oscillatoria sp.			x			
Phormidium tenue (Menegh.) Gomont	x		x	x	x	
Spirulina major Kuetzing				x	x	
Tolypothrix distorta Kuetzing			x			
CHLOROPHYTA						
Ankistrodesmus falcatus (Corda) Ralfs	x		x			x
Chlamydomonas globosa Snow			x		x	
Cladophora glomerata (Lemm.) Kuetzing	x		x			
Closterium dianae Ehrenberg				x		
Cosmarium nitidulum De Not.						x
Cosmarium sp.				x	x	x
Dictyosphaerium ehrenbergianum Neageli						x
Eudorina elegans Ehrenberg						x
Mougeotia sp.					x	x
Oedogonium sp. 1	x		x	x	x	
Oedogonium sp. 2			x			
Oedogonium sp. 3	x		x	x	x	
Oedogonium sp. 4			x	x	x	
Oedogonium sp. 5	x		x	x	x	x
Oedogonium sp. 6	x					
Oocystis gloeocystiformis Borge						x
Oocystis pusilla Hansgirg			x			
Pediastrum boryanum (Turp.) Meneghini						x
Rhizoclonium hieroglyphicum (Ag.) Kuetzing	x		x	x	x	
Rhizoclonium sp.			x			
Scenedesmus bijuga (Turp.) Lagerheim						x
Scenedesmus quadricauda var. *longispina* (Chod.) G.M. Smith				x		
Scenedesmus quadricauda var. *quadrispina* (Turp.) Brebisson					x	
Sphaerocystis schroeteri Chodat						x
Spirogyra sp. 1				x	x	
Spirogyra sp. 2			x	x		
Spirogyra sp. 3			x	x	x	
Spirogyra sp. 4			x	x	x	
Spirogyra sp. 5	x		x	x	x	x

Table 2 continued.

Species	Inflow	Benthos	Epiphyton	Epipsammon	Epilithon	Plankton
Staurastrum gracile(?) Ralfs						x
Ulothrix zonata (Weber et Mohr) Kuetzing	x			x		
Zygnema sp.			x	x		
EUGLENOPHYTA						
Euglena elastica Prescott				x		
Euglena gracilis Klebs			x			x
Trachelomonas abrupta (Swir.) Deflandre			x			x
Trachelomonas dybowskii Drezepolski			x			x
PYRRHOPHYTA						
Ceratium hirudinella (O.F. Muell.) Dujardin						x
Glenodinium pulvisculus (Ehr.) Stein				x	x	
CHRYSOPHYTA						
Dinobryon divergens Imhof			x	x	x	x
BACILLARIOPHYTA						
Achnanthes clevei Grunow			x	x		x
Achnanthes conspicua A. Mayer				x		x
Achnanthes exigua Grunow			x	x	x	x
Achnanthes gibberula Grunow						x
Achnanthes hauckiana Grunow			x	x	x	x
Achnanthes kryophila Petersen			x			x
Achnanthes lanceolata (Breb.) Grunow			x	x	x	x
Achnanthes lanceolata var. *dubia* Grunow			x	x		
Achnanthes linearis (W.Sm.) Grunow			x	x	x	x
Achnanthes linearis f. *curta* H.L. Smith						x
Achnanthes minutissima Kuetzing			x	x	x	x
Achnanthes orientalis Hustedt						x
Achnanthes peragalli var. *fossilis* Tempere & Peragallo				x		
Achnanthes sp. 1			x			x
Achnanthes sp. 2			x			x
Amphipleura pellucida Kuetzing				x		
Amphora coffeiformis (Ag.) Kuetzing			x	x		x
Amphora ovalis (Kg.) Kuetzing				x		x
Amphora ovalis var. *affinis* (Kg.) v. Heurck ex De Toni						x
Amphora ovalis var. *pediculus* (Kg.) v. Heurck ex De Toni				x	x	x
Amphora perpusilla (Grun.) Grunow			x	x	x	x
Amphora veneta Kuetzing			x	x	x	x
Anomoeoneis serians (Breb. ex Kg.) Cleve			x			
Anomoeoneis serians var. *brachysira* (Breb. ex Kg.) Hustedt						x
Anomoeoneis sphaerophora (Kg.) Pfitzer						x
Anomoeoneis zellensis (Grun.) Cleve			x	x		
Asterionella formosa Hassall			x	x		x
Bacillaria paxillifer (O. Muell.) Hendey						x
Biddulphia levis Ehrenberg						x
Caloneis amphisbaena (Bory) Cleve					x	
Caloneis bacillum (Grun.) Cleve			x	x	x	x
Caloneis lewisii Patrick			x	x	x	x
Caloneis lewisii var. *inflata* (Schultze) Patrick			x	x		x
Caloneis ventricosa var. *truncatula* (Grun.) Meister			x			x
Chaetoceros sp.						x
Cocconeis pediculus Ehrenberg			x	x		
Cocconeis placentula Ehrenberg			x			

Table 2 continued.

Species	Inflow	Benthos	Epiphyton	Epipsammon	Epilithon	Plankton
Cocconeis placentula var. *euglypta* (Ehr.) Cleve			x			
Cocconeis placentula var. *lineata* (Ehr.) Cleve	x	x				x
Cyclotella caspia Grunow						x
Cyclotella comta (Ehr.) Kuetzing	x	x	x			x
Cyclotella meneghiniana Kuetzing						x
Cyclotella sp.						x
Cylindrotheca gracilis (Breb.) Grunow	x	x	x			x
Cymatopleura solea (Breb.) W. Smith	x					x
Cymbella affinis Kuetzing	x	x				x
Cymbella brehmii Hustedt	x	x				x
Cymbella cuspidata Kuetzing	x					
Cymbella cymbiformis Agardh	x	x	x			
Cymbella mexicana (Ehr.) Cleve		x				x
Cymbella microcephala Grunow	x	x	x			x
Cymbella minuta Hilse ex Rabenhorst	x					
Cymbella minuta var. *latens* (Krasske) Reimer	x					
Cymbella minuta var. *silesiaca* (Bleisch ex Rabh.) Reimer	x	x	x			
Cymbella muelleri Hustedt	x	x				
Cymbella norvegica Grunow		x				
Cymbella sinuata Gregory	x	x				x
Cymbella tumida (Breb.) v. Heurck	x					
Cymbella turgidula Grunow		x				
Cymbella sp. 1						x
Cymbella sp. 2	x	x				
Denticula elegans f. *valida* Pedicino		x				
Denticula sp.	x	x	x			
Diatoma tenue Agardh	x	x				x
Diatoma tenue var. *elongatum* Lyngbye	x					x
Diploneis oculata (Breb.) Cleve	x					x
Diploneis subovalis Cleve	x	x	x			x
Entomoneis ornata (Bail.) Reimer		x				
Epithemia adnata var. *proboscidea* (Kg.) Patrick	x	x	x			x
Epithemia argus var. *protracta* A. Mayer						x
Epithemia smithii Carruthers	x	x	x			
Epithemia sorex Kuetzing	x	x	x			x
Epithemia turgida (Ehr.) Kuetzing	x	x				x
Fragilaria brevistriata Grunow	x					
Fragilaria brevistriata var. *inflata* (Pant.) Hustedt	x	x	x			x
Fragilaria cf *capucina* Desmazieres	x	x				
Fragilaria capucina var. *mesolepta* Rabenhorst	x					
Fragilaria construens var. *venter* (Ehr.) Grunow		x				x
Fragilaria crotonensis Kitton	x	x	x			x
Fragilaria crotonensis var. *oregonica* Sovereign	x					x
Fragilaria leptostauron (Ehr.) Hustedt	x	x				x
Fragilaria leptostauron var. *dubia* (Grun.) Hustedt	x	x	x			
Fragilaria pinnata Ehrenberg	x	x	x			x
Fragilaria similis Krasske						x
Fragilaria vaucheriae (Kg.) Peterson	x	x	x			x
Fragilaria virescens Ralfs	x					x
Frustulia vulgaris (Thw.) De Toni		x				
Gomphonema acuminatum Ehrenberg	x					
Gomphonema affine Kuetzing	x					
Gomphonema dichotomum Kuetzing	x					
Gomphonema instabilis Hohn & Hellerman	x	x				x
Gomphonema intricatum Kuetzing	x					

Table 2 continued.

Species	Inflow	Benthos	Epiphyton	Epipsammon	Epilithon	Plankton
Gomphonema olivaceum (Lyngb.) Kuetzing	x					x
Gomphonema olivaceum var. *calcarea* (Cl.) Cleve	x					
Gomphonema parvulum Kuetzing	x	x				x
Gomphonema parvulum var. *micropus* (Kg.) Cleve	x	x				x
Gomphonema subclavatum (Grun.) Grunow	x	x				
Gomphonema truncatum Ehrenberg	x					
Gomphonema sp.	x					
Gyrosigma acuminatum (Kg.) Rabenhorst	x	x	x			x
Gyrosigma fasciola (Ehr.) Griffith & Henfrey						x
Gyrosigma obtusatum (Sulliv. & Wormley) Boyer	x	x	x			
Hannaea arcus (Ehr.) Patrick	x					
Hantzschia amphioxys (Ehr.) Grunow						x
Hantzschia distincte-punctata (Hust.) Hustedt	x					x
Hantzschia virgata (Roper) Grunow	x					
Mastogloia braunii Grunow						x
Mastogloia smithii var. *lacustris* Grunow	x	x	x			x
Melosira granulata (Ehr.) Ralfs						x
Navicula anglica Ralfs						x
Navicula anglica var. *subsalsa* (Grun.) Cleve	x	x	x			x
Navicula arvensis Hustedt	x	x	x			x
Navicula atomus (Kg.) Grunow	x					
Navicula bacilliformis Grunow						x
Navicula capitata Ehrenberg	x					x
Navicula capitata var. *hungarica* (Grun.) Ross		x				x
Navicula capitata var. *lunebergensis* (Grun.) Patrick		x				x
Navicula cincta (Ehr.) Ralfs						x
Navicula circumtexta Meister ex Hustedt		x				x
Navicula clementoides Hustedt		x				
Navicula contenta f. *biceps* (Arnot.) Grunow						x
Navicula cryptocephala Kuetzing		x				
Navicula cryptocephala var. *exilis* (Kg.) Grunow						x
Navicula cryptocephala var. *veneta* (Kg.) Rabenhorst	x	x	x			x
Navicula cuspidata (Kg.) Kuetzing	x	x				
Navicula decussis Oestrup	x	x				x
Navicula disjuncta Hustedt		x				x
Navicula elginensis (Greg). Ralfs			x			
Navicula exigua var. *capitata* Patrick		x				
Navicula gastrum Ehrenberg		x				x
Navicula graciloides A. Mayer						x
Navicula grimmei Krasske		x				x
Navicula halophila (Grun.) Cleve						x
Navicula halophila f. *tenuirostris* Hustedt		x				x
Navicula heufleri Grunow		x				
Navicula heufleri var. *leptocephala* (Breb. ex Grun.) Patrick	x	x	x			x
Navicula luzonensis Hustedt	x	x				
Navicula menisculus var. *upsaliensis* (Grun.) Grunow	x	x	x			x
Navicula minima Grunow		x	x			x
Navicula mutica var. *cohnii* (Hilse) Grunow	x	x	x			x
Navicula mutica var. *undulata* (Hilse) Grunow	x	x				
Navicula oblonga Kuetzing						x
Navicula pelliculosa (Breb. ex Kg.) Hilse	x	x	x			x
Navicula peregrina (Ehr.) Kuetzing	x	x				
Navicula permitis Hustedt	x	x				x
Navicula pupula Kuetzing	x	x	x			x
Navicula pupula var. *mutata* (Krasske) Hustedt	x					

Table 2 continued.

Species	Inflow	Benthos	Epiphyton	Epipsammon	Epilithon	Plankton
Navicula pupula var. *rectangularis* (Greg.) Grunow	x	x				
Navicula pygmaea Kuetzing						x
Navicula radiosa Kuetzing	x	x				
Navicula radiosa var. *tenella* (Breb. ex Kg.) Grunow	x	x				x
Navicula rhynchocephala Kuetzing		x				
Navicula salinarum var. *intermedia* (Grun.) Cleve	x	x	x			x
Navicula secreta var. *apiculata* Patrick	x	x	x			x
Navicula tantula Hustedt	x	x				x
Navicula tenelloides Hustedt						x
Navicula tenera Hustedt	x	x	x			x
Navicula tripunctata (Muehl.) Bory						x
Navicula tripunctata var. *schizonemoides* (v. Heurck) Patrick	x	x	x			x
Navicula viridula (Kg.) Kuetzing			x			
Navicula viridula var. *linearis* Hustedt		x				
Navicula viridula var. *rostellata* (Kg.?) Cleve		x				x
Navicula sp. 1						x
Navicula sp. 2	x	x				x
Navicula sp. 3						x
Navicula sp. 4		x				
Navicula sp. 5		x				
Navicula sp. 6			x			
Neidium bisulcatum var. *baicalense* (Skr. & Meyer) Reimer		x				
Neidium dubium (Ehr.) Cleve	x	x				x
Nitzschia acicularis W. Smith	x					
Nitzschia acicularoides Hustedt	x					x
Nitzschia cf *amphibia* Grunow	x					x
Nitzschia angustata (W. Sm.) Grunow	x	x	x			x
Nitzschia apiculata (Greg.) Grunow			x			
Nitzschia circumsuta (?) (Bail.) Grunow						x
Nitzschia dissipata (Kg.) Grunow	x	x	x			x
Nitzschia frustulum Kuetzing	x	x				x
Nitzschia gandersheimensis Krasske		x	x			x
Nitzschia hantzschiana Rabenhorst	x	x	x			x
Nitzschia hungarica Grunow		x				x
Nitzschia inconspicua Grunow	x	x	x			x
Nitzschia microcephala Grunow	x	x	x			x
Nitzschia minutula Grunow	x	x	x			x
Nitzschia ovalis Arnott	x	x				x
Nitzschia palea (Kg.) W. Smith	x	x	x			x
Nitzschia paleacea Grunow	x	x	x			x
Nitzschia punctata (W. Sm.) Grunow	x					
Nitzschia pusilla (Kg.) Grun. em. Lange-Bertalot	x	x	x			x
Nitzschia recta Hantzsch	x	x	x			x
Nitzschia romana Grunow	x	x				x
Nitzschia sigma var. *sigmatella* Grunow		x				x
Nitzschia sigmoidea (Ehr.) W. Smith	x	x				x
Nitzschia sinuata (W. Sm.) Grunow						x
Nitzschia sinuata var. *tabellaria* Grunow	x	x	x			
Nitzschia sociabilis Hustedt						x
Nitzschia trybionella var. *debilis* (Arnott) A. Mayer		x				x
Nitzschia trybionella cf var. *levidensis* (W. Sm.) Grunow						x
Nitzschia trybionella var. *victoriae* Grunow						x
Nitzschia valdestriata Aleem & Hustedt	x	x	x			
Nitzschia sp. 1	x	x	x			x
Nitzschia sp. 2	x	x				x

Table 2 continued.

Species	Inflow	Benthos	Epiphyton	Epipsammon	Epilithon	Plankton
Pinnularia abaujensis var. *linearis* (Hust.) Patrick	x					
Pinnularia borealis Ehrenberg			x			
Pinnularia brebissonii Kuetzing	x					
Pinnularia brebissonii var. *diminuta* (Grun.) Cleve.						x
Pleurosigma sp.		x				
Rhoicosphenia curvata (Kg.) Grunow		x				x
Rhopalodia gibba (Ehr.) O. Mueller	x	x				x
Rhopalodia gibberula (Ehr.) O. Mueller		x				
Rhopalodia gibberula var. *vanheurckii* O. Mueller	x	x	x			x
Stauroneis anceps Ehrenberg	x					
Stauroneis smithii Grunow		x				
Stauroneis cf *smithii* Grunow						x
Stauroneis wislouchii Por. et Anisim.	x	x	x			x
Stephanodiscus astraea var. *minutula* (Kg.) Grunow						x
Stephanodiscus niagarae Ehrenberg						x
Stephanodiscus sp.						x
Surirella angusta Kuetzing		x				
Surirella ovalis Brebisson	x	x				x
Synedra acus Kuetzing	x	x				x
Synedra cyclopum Brutschi						x
Synedra fasciculata (Ag.) Kuetzing	x	x				x
Synedra fasciculata var. *truncata* (Grev.) Patrick						x
Synedra pulchella Kuetzing	x		x			x
Synedra radians Kuetzing	x					
Synedra ulna (Nitzsch) Ehrenberg	x	x				x
Synedra ulna var. *ramesi* (Herib. et Perag.) Hustedt		x				

Zygnematales (*Spirogyra*, *Mougeotia*, and *Zygnema* species), though *Oedogonium* species were also important. Because sexual stages were not observed, these taxa could not be identified beyond the generic level. *Cladophora glomerata* was important in the inlet channel but was also occasionally common in some littoral sites of the reservoir. *Ulothrix zonata* was abundant in the channel in November, but was only rarely observed in the reservoir. Diatoms were also important in the littoral communities, and dominated the algal assemblage during the winter and early spring. Filamentous Chlorophyta died off during the winter and were not reestablished until early summer. Diatoms on the other hand recovered soon after winter ice had melted. The eight most important diatoms in the littoral sites were all pennate species; *Diatoma tenue, Fragilaria vaucheriae, Gomphonema instabilis, Navicula cryptocephala* var. *veneta*, *Navicula mutica* var. *cohnii*, *Nitzschia minutula*, *Nitzschia palea*, and *Nitzschia paleacea* (Table 3).

The three different substrata sampled showed differences in diatom floras. *Cocconeis placentula* var. *lineata*, *Cymbella minuta* var. *silesiaca*, *Gomphonema olivaceum*, and *Gomphonema instabilis* were primarily epiphytes. The epipsammon was characterized by small raphoid diatoms, particularly *Navicula mutica* var. *cohnii.* Filamentous green algae were either unattached or part of the epilithon and epiphyton. Most algal species in the littoral were at least to some degree cosmopolitan.

Many algal species are opportunistic generalists (Lowe 1974, Patrick and Reimer 1966). *Achnanthes minutissima*, *Navicula cryptocephala* var. *veneta*, *Nitzschia palea*, and *Nitzschia paleacea*, as well as several other small raphoid diatom species in the study, are such taxa. These organisms occur in a wide variety of habitats in western North America and worldwide (Camburn et al. 1978, Foged 1959, 1974, Hustedt 1930, 1949, Patrick and Reimer 1966). Other diatoms are best suited to grow in more specialized env ronments. For example, many species in the genus *Cocconeis* grow optimally on submerged macrophytes (Lowe 1974, Patrick and Reimer 1966). These species can also be found on rocks or wood and, through mixing processes in the lake, will also occur in the epipsammon and plankton. Because species are not confined to the substrate on which they are best suited, characterizing species according to habitat preference is often difficult. Even so, the planktonic algal assemblages in Bottle Hollow Reservoir were distinctly different from those of the littoral, despite the overlap of some species. The dominant algal plankters were limited to three diatom taxa and one chrysophyte; *Asterionella formosa*, *Cyclotella comta*, *Fragilaria crotonensis*, and *Dinobryon divergens* (Table 3). These species usually composed about 80 percent of the total planktonic flora. Because of this, diversity was much lower in the plankton than in the periphyton. Total phytoplankton abundance ranged from an average density as low as 700,000 organisms per liter in late July to a high of 1,700,000 organisms per liter in November.

Discussion

Three areas of interest concerning the floras of Bottle Hollow Reservoir will be discussed; floristic diversity, community dynamics, and trophic condition. It has already been noted that diversity in the planktonic environment was depressed by the dominance of four algal taxa. Even so, a total of 174 algal taxa (154 of which were diatoms) were found in the phytoplankton samples. This is 60 species fewer than found in the littoral zone, which had a total of 234 taxa (184 of which were diatoms). The diversity in phytoplankton was due primarily to the infrequent occurrence of small diatom species in the water column. These species are easily transferred from the littoral and benthic areas, where they are often most common, to the open water of the lake by natural mixing processes. A few supposed littoral species such as *Achnanthes orientalis* were more common in the plankton than in the littoral collections, but these were more the exception than the rule. Because the majority of the littoral-planktonic diatoms were small, they were found primarily in nannoplankton samples and were much less frequent in the netplankton. Netplankton samples had an average of 16 diatom taxa per sample, whereas nannoplankton collections contained an average of 30 taxa (Table 4). Littoral collections contained substantially greater numbers of species. This is to be expected because the littoral environment is more heterogenous than the planktonic habitat and contains more ecological niches. The highest number of species per sample was found in the November littoral collections (Table 4).

Population dynamics of the plankton are easier to monitor than those for the littoral areas. This is largely due to the relative ease of obtaining quantitative phytoplankton data versus quantitative data for attached species. If the numbers of netplankton individuals per liter are added to the numbers of nannoplankton individuals per liter from the same locality, estimates of total phytoplankton per liter of lake water are obtained. Average densities of the four most abundant taxa were computed using these estimates and plotted against time (Fig. 2). *Fragilaria crotonensis* was the most abundant species, reaching higher concentrations as the seasons progressed. The highest density of this taxon was observed in the November 1979 collections.

Several observations and speculations can be made after consideration of the data shown in Figure 2. Two periods of peak algal production, fall and spring, occur in Bottle

Table 3. Average percent densities of the 14 most important diatom taxa in Bottle Hollow Reservoir. Average densities were computed separately for plankton and littoral samples.

Species	Plankton	Littoral
Achnanthes minutissima	.3	2.5
Asterionella formosa	25.5	.4
Cyclotella comta	17.1	.7
Cymbella microcephala	.2	2.2
Diatoma tenue	.4	3.8
Fragilaria crotonensis	39.5	1.6
Fragilaria vaucheriae	.1	3.1
Gomphonema instabilis	.1	3.9
Navicula cryptocephala var. *veneta*	.4	8.4
Navicula mutica var. *cohnii*	.1	7.9
Nitzschia microcephala	.2	2.1
Nitzschia minutula	.1	3.2
Nitzschia palea	2.1	3.8
Nitzschia paleacea	2.7	4.8

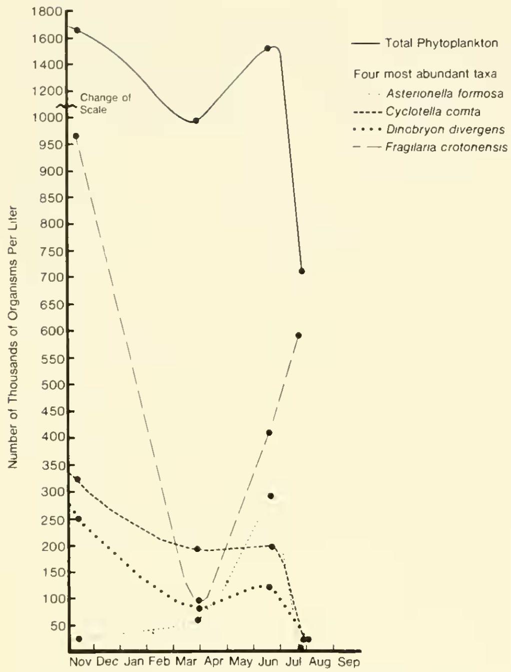


Fig. 2. Densities of the dominant phytoplankters and total phytoplankton through the 1979–1980 collecting year in Bottle Hollow Reservoir.

Hollow Reservoir. These are likely due to fall and spring turnover. During winter, production falls drastically with shorter days and ice coverage. As soon as the ice melts, small diatoms grow quickly in the recently mixed, nutrient-rich water. The March collections had substantial numbers of these small diatoms, even though the biomass was still quite low. *Cyclotella comta* was present in higher numbers than *F. crotonensis* at this time.

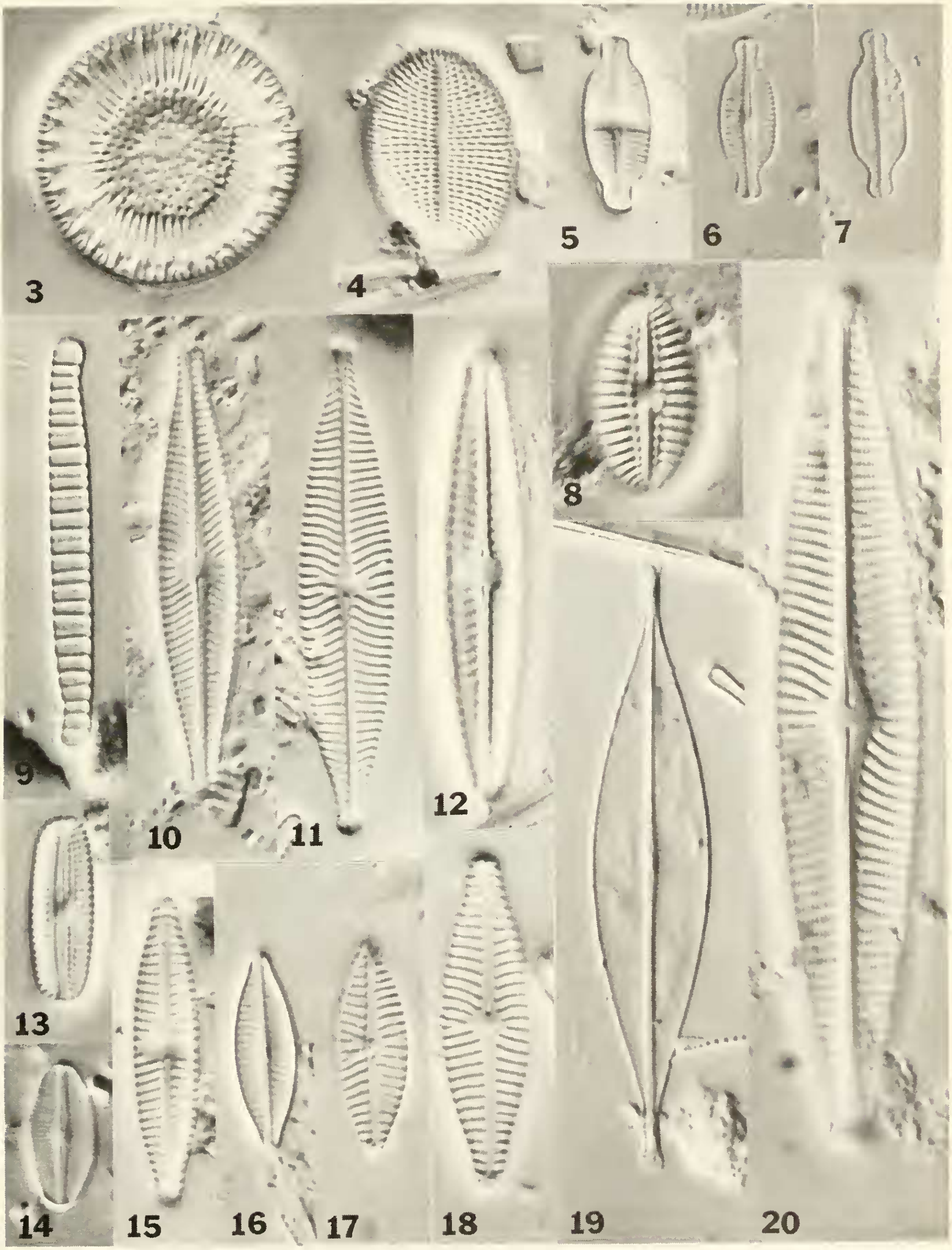
The pulse of these small algae favors the growth of small filter-feeder zooplankton (Porter 1977), such as the cladocerans that were observed in both the March and June net hauls. As the zooplankters apply a selective pressure on small diatoms, larger (often colonial) algae may become more prevalent (Porter 1977, Wimpenny 1973). The density of *Cyclotella comta* in Bottle Hollow Reservoir leveled off in June and dropped drastically in July. The larger colonial forms *Asterionella formosa*, *Dinobryon divergens*, and *Fragilaria crotonensis* increased in late spring and dominated the spring peak.

As summer progressed, total phytoplankton density dropped, though *F. crotonensis* continued to increase in number. This may be due to two factors. First, the lake begins to stratify during early spring, causing mixing to cease. Nutrients tied up in the living algae and zooplankton are lost to the sediments as these organisms die and sink and as feces of zooplankton and fish settle (Wetzel 1975). Second, grazing pressure may decrease total phytoplankton density as zooplankton populations reach maturity (Porter 1977). Filter-feeders cannot feed well on the large *Fragilaria* colonies, and so *F. crotonensis* tends to escape predation and continues to increase in number. An unexplained phenomena is the decrease in the large colonial algae *Asterionella formosa* and *Dinobryon divergens*, which should also have the same size refuge from filter feeders as *F. crotonensis*. The decline of *A. formosa* in early summer is a common occurrence that has been attributed to nutrient depletion in the upper water (Pearsall 1932). Another possibility is that larger raptorian-feeder zooplankton, such as many copepods, which begin to reach maturity later in summer, may have a preference for these algae over *F. crotonensis*. Finally, it is clear that either or both of these algae could decrease due to temperature increase or some other environmental factor.

Littoral algal succession was less well defined. Diatoms were particularly important in early spring and grew to some extent when the lake was covered with ice. As the water warmed, filamentous green algae became important and had the highest standing crop. Despite the higher biomass of these green algae, diatoms may be more critical to littoral

Table 4. Average number of diatom species per microhabitat type.

Microhabitat	November	March	June	July	Average
Netplankton	18.4	12.4	22.0		16.0
Nannoplankton	18.2	40.4	21.0	51.0	30.4
Epiphyton	75.5	46.5	62.0		61.2
Epipsammon	63.5	21.5	48.0	64.0	50.9



Figs. 3–20. Diatom spp.: 3, *Cyclotella comta*, 19 mm diameter, 12 striae/10 mm; 4, *Cocconeis placentula* var. *lineata*, 15 × 11 mm, 19 striae/10 mm; 5, *Achnanthes exigua*, 12.5 × 5 mm, 24 striae/10 mm; 6, *A. orientalis*, Raphe valve: 11.5 × 4 mm, 26–30 striae/10 mm; 7, *A. orientalis*, Rapheless valve: 12 × 4 mm, 26–30 striae/10 mm; 8, *Diploneis subovalis*, 14 × 8.5 mm, 11 costae/10 mm; 9, *Diatoma tenue*, 29 × 3 mm, 7–10 costae/10 mm; 10, *Navicula cryptocephala*, 32 × 6 mm, 15–18 striae/10 mm; 11, *N. salinarum* var. *intermedia*, 35 × 7 mm, 14–16 striae/10 mm; 12, *N. tripunctata*, 32 × 6 mm, 12–14 striae/10 mm; 13, *N. tenera*, 13 × 4.5 mm, 20 striae/10 mm; 14, *N.* sp. 3, 10 × 5 mm, 30 striae/10 mm; 15, *N. cryptocephala* var. *veneta* (?), 22 × 5 mm, 14–16 striae/10 mm; 16, *N. cryptocephala* var. *exilis*, 14 × 4.5 mm, 20 striae/10 mm; 17, *N. cryptocephala* var. *veneta*, 15 × 5.5 mm, 14–15 striae/10 mm; 18, *N. cryptocephala* var. *veneta*, 24 × 7 mm, 13–14 striae/10 mm; 19, *N. halophila* f. *tenuirostris*, 43 × 8.5 mm, 26 striae/10 mm; 20, *N. radiosa*, 60 × 11 mm, 9–12 striae/10 mm. All photographs are 2000X.

food webs. The annual production of the diatoms may exceed the production of the other algae because of their faster growth rates. The higher production of diatoms is not readily evident because grazers often keep their biomass low (Minshall 1978).

Interactions between the littoral and planktonic communities exist, though the extent of this interaction is difficult to assess. Planktonic species were found in the periphyton, and many littoral raphoid pennate diatoms occurred commonly in the plankton. Most freshwater phytoplankton are thought to have a neritic phase in which they dwell on the bottom, often in a resting stage (Patrick and Reimer 1966). This neritic phase would partly explain the occurrence of phytoplankton in near shore areas, though drift and settling are also factors. Likewise, many attached algae may become unattached and drift with the plankton, which could be adaptive by helping increase their distribution.

The data collected during this study indicate that Bottle Hollow Reservoir is a mesotrophic to mesotrophic-eutrophic body of water. There are several evidences for this conclusion. First, biotic diversity is higher than in most eutrophic systems in the same region but lower than in many oligotrophic systems. The littoral samples with high num bers of species and absence of dominants indicate fairly unpolluted waters. Second, the successional pattern is not characteristic of

Figs. 21–31. Diatom spp.: 21, *Gomphonema olivaceum*, 23 × 6 mm, 13–15 striae/10 mm; 22, *Gomphonema parvulum*, 24 × 5.5 mm, 14–16 striae/10 mm; 23, *G. intricatum*, 17 × 4 mm, 12–13 striae/10 mm; 24, *G. intricatum*, 28 × 5 mm, 10–14 striae/10 mm; 25, *G. instabilis*, 34 × 7 mm, 12–18 striae/10 mm; 26, *Nitzschia romana*, 20 × 3.5 mm, 26 striae/10 mm, 9–10 fibulae/10 mm; 27, *Amphora perpusilla*, 11 × 3 mm, 19 striae/10 mm; 28, *Cymbella microcephala*, 15 × 4.5 mm, 26–27 striae/10 mm; 29, *Nitzschia valdestriata*, 10 × 2.5 mm, 10 striae/10 mm, 10 fibulae/10 mm; 30, *N. sinuata* var. *tabellaria*, 18 × 7 mm, 20 striae/10 mm, 5–6 fibulae/10 mm, 31, *N. recta*, 52 × 6 mm, 7–9 fibulae/10 mm. All photographs are 2000X.

eutrophic waters because blue-green algae do not play an important role. In the plankton of most eutrophic lakes and reservoirs of temperate regions, the large diatoms and chrysophytes are succeeded by blue-green species in late summer, particularly *Aphanizomenon flos-aquae* and species of *Anabaena* (Wetzel 1975, Whiting et al. 1978). Such succession to Cyanophyta did not occur in Bottle Hollow Reservoir. Blue-green algae were also an insignificant part of the periphyton. Third, most diatoms we encountered (some of which are used as water quality indicators), were typical of mesotrophic waters. The two dominants, *Asterionella formosa* and *Fragilaria crotonensis*, are considered indicative of mesotrophic to eutrophic water (Lowe 1974, Wetzel 1975). It should be mentioned that several species we collected often indicate eutrophic water, specifically *Fragilaria vaucheriae, Navicula cryptocephala* var. *veneta, Nitzschia minutula, Nitzschia palea*, and *Nitzschia paleacea* (Lowe 1974). Nevertheless, we have observed in our studies that these are opportunistic species that occur throughout western North America in a wide variety of habitats (Anderson and Rushforth 1976, Benson and Rushforth 1975, Johansen and Rushforth 1981, Lawson and Rushforth 1975, St. Clair and Rushforth 1976, 1978). When these species dominate a system to the exclusion of more mesotrophic organisms, they provide important evidence for eutrophy. When they are present in lower numbers, together with high numbers of other algal species (conditions we found in Bottle Hollow Reservoir) they do not necessarily indicate eutrophic conditions.

The fourth confirmation of mesotrophic to mesotrophic-eutrophic water is the assemblage of saprobic indicator diatoms. The saprobien spectrum was first proposed by Kolkwitz and Marsson (1908) and is a tool for assessing water quality with respect to organic loading and pollution. All diatoms in Bottle Hollow Reservoir were checked against Lowe (1974). There were 23 mesosaprobic taxa, 28 oligosaprobic taxa, 12 saproxenous taxa, and one saprophobic species. This assemblage is evidence for water that often has a moderate to high amount of dissolved organic nutrients. It also indicates, however, that there are periods when oxidation is complete and water is quite "clean." Using Lowe (1974), it was also discovered that the majority of the diatoms are alkaliphilous.

Our studies of Bottle Hollow Reservoir have shown that the biological water quality of this body of water is quite good, particularly when compared to eutrophic systems in the same region. Even so, because of the high amounts of nutrients found naturally in the rocks of the drainage basins of eastern Utah, care must be taken to limit the human-caused introduction of pollutants into this system. We believe Bottle Hollow Reservoir has the potential to maintain a healthy fishery but also has the potential for rapid deterioration toward eutrophy.

Literature Cited

Anderson, D. C., and S. R. Rushforth. 1976. The cryptogamic flora of desert soil crusts in southern Utah, USA. Nova Hedwigia 28:691–729.

Benson, C. E., and S. R. Rushforth. 1975. The algal flora of Huntington Canyon, Utah, USA. Bibliotheca Phycologica 18:1–177.

Camburn, K. E., R. L. Lowe, and D. L. Stoneburner. 1978. The haptobenthic diatom flora of Long Branch Creek, South Carolina. Nova Hedwigia 30:149–279.

Foged, N. 1959. Diatoms from Afghanistan. Biol. Skr. Det Kongl. Dan. Vid. Selsk. 11(1):1–95.

_____. 1974. Freshwater diatoms in Iceland. Bibliotheca Phycologica 15:1–118.

Hustedt, F. 1930. Bacillariophyta (Diatomeae). *In* A. Pascher, Die Susswasser-Flora Mitteleuropas, Heft 10, Gustav Fisher, Jena, Germany. 468 pp.

_____. 1949. Susswasser-Diatomeen aus dem Albert-Nationalpark in Belgisch-Kongo. Exploration du Parc National Albert, Mission H. Damas (1935–1936) 8:1–199. Inst. Parcs Nat. Congo Belge, Hayez, Bruxelles.

Johansen, J. R., and S. R. Rushforth. 1981. Diatoms of surface waters and soils of selected oil shale lease areas of eastern Utah, USA. Nova Hedwigia 34:333–389.

Kolkwitz, R., and M. Marsson. 1908. Okologie der pflanzlichen Saprobien. Ber. Deut. Bot. Ges. 26:505–519.

Lawson, L. L., and S. R. Rushforth. 1975. The diatom flora of the Provo River, Utah, USA. Bibliotheca Phycologica 17:1–149.

Lowe, R. L. 1974. Environmental requirements and pollution tolerance of freshwater diatoms. Environmental Monitoring Series, U.S. Environmental Protection Agency, Report No. EPA-670/4-74-005. 334 pp.

Merritt, L., S. Rushforth, J. Johansen, R. Heckman, R. Winget, and W. Brimhall. 1980. Assessment of water quality in Bottle Hollow Reservoir. Report to Ute Indian Tribe, Duchesne Co., Ut. 180 pp.

MINSHALL, G. W. 1978. Autotrophy in stream ecosystems. BioScience 28(12):767–771.

PATRICK, R., AND C. W. REIMER. 1966. The diatoms of the United States, I. Acad. Nat. Sci. Philad. Mon. 13. 1–688 pp.

PEARSALL, W. H. 1932. Phytoplankton in the English Lakes. II. The composition of the phytoplankton in relation to dissolved substances. J. Ecology 20(2):241–262.

PORTER, K. G. 1977. The plant-animal interface in freshwater ecosystems. Am. Scientist 65:159–170.

ST. CLAIR, L. L., AND S. R. RUSHFORTH. 1976. The diatoms of Timpanogos Cave National Monument, Utah. Amer. J. Bot. 63(1):49–59.

———. 1978. The diatom flora of the Goshen Playa and wet meadow. Nova Hedwigia 29:191–229.

WETZEL, R. G. 1975. Limnology. W. B. Saunders Company, Philadelphia, Penn. 743 pp.

WHITING, M. C., J. D. BROTHERSON, AND S. R. RUSHFORTH. 1978. Environmental interaction in summer algal communities of Utah Lake. Great Basin Nat. 38(1):31–41.

WIMPENNY, R. S. 1973. The size of diatoms. V. The effect of animal grazing. J. Mar. Bio. Assoc. United Kingdom 53:957–974.